MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CLARK UNIVERSITY.

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I.

INTRODUCTION.

In beginning the publication of this series of minor laboratory studies, a word of explanation as to their nature seems appropriate. The aim of the laboratory in Clark University is original research, not only for itself, but as a pedagogical means. Many students, however, come to us from institutions in which psychological laboratories have not as yet been founded, and sometimes with no training in experimental science at all, and are therefore more or less unfitted to enter at once upon research work. For this reason the first year in the laboratory is devoted largely to practice experiments, such as those collected in the Laboratory Course already published in part in this *Journal*; but an essential part of each student's work during the year is the execution of some small and definite piece of experimental research, assigned by the director of the laboratory and worked out, after some months of general laboratory practice, under his supervision and generally with his active assistance at the start. The first six of the following papers give the results of such studies. The greater number of papers published under the title of "Minor Studies" will be of this character, but others will also be included (as in this instance that on the Pendulum Chronograph) when their length and subject matter are fitting.

ON THE DISCRIMINATION OF GROUPS OF RAPID CLICKS.

BY THADDEUS L. BOLTON.

With reference to groups of rapid clicks several questions may be asked, among others the following: 1. Is the rate at which the clicks of the group fuse into a continuous tone or noise dependent upon the number of clicks in the group, so

that a small group can be recognized as composed of discrete clicks when a larger group cannot?[1] 2. In the perception of a group that does not fuse, is there a tendency for any of the clicks to drop out, as Hall and Jastrow found that they tended to do when counting was added to simple perception? 3. Can the presence of one more or one less click be recognized when successive groups of different number of clicks are given, and under what conditions as to rate and number? The experiments about to be described have immediate bearing on the last of these, but throw more or less light also on the first and second.

Apparatus and Methods. In such experiments as these, the great difficulty is to get an instrument that will produce a sound of the greatest possible clearness and definition in controllable number and at regular intervals. The required sound was found in the click of the armature of a time-marker of the pattern furnished by the Cambridge Scientific Instrument Co. This sound was produced at the closing of the circuit; the sound at the break was avoided by making the armature react against a piece of soft India rubber. Though the avoidance of this break sound was not absolutely complete, it was not sufficiently loud to interfere with that at the make, and in general was wholly unnoticed. All that was required now to get a regular succession of uniform clicks was to make and break the circuit at regular intervals. This was accomplished by causing a heavy pendulum to draw a projecting platinum point across a series of equal brass plates separated by pieces of hard rubber of uniform thickness. Each plate was connected by a wire with a switch-board, which made it possible to add or subtract one or more of the clicks by throwing one or more of the plates into or out of connection with the time-marker. What was needed for the experiment, however, was not one series of clicks, but two separated by a short interval. To accomplish this, a second platinum point was attached to the pendulum at a suitable distance behind the other. From these platinum points a wire ran up the pendulum bar into a mercury cup opposite its centre of oscillation, thence to the battery (12 Leclanché cells), to the time-marker, and to the switch-board, thus completing the circuit. The pendulum used was like that devised by Drs. Bowditch and Warren, of which a full description may be found in the *Journal of Physiology*.[2] The especial value of such a pendulum for this work lies in the fact that its

[1] Suggested, but not worked out to any extent, by Hall and Jastrow. *Mind*, XI. 1886, 58.

[2] Vol. IX. page 29.

velocity in the different parts of its arc varies less than that of ordinary pendulums. To prevent the friction of the platinum points from affecting the rate of the pendulum, and also to insure a better contact, they were attached to brass wire springs. The pendulum swung each time from a fixed position, where it was held till the required instant by a magnet. To prevent the points making contact at the backward swing of the pendulum, the set of brass plates was attached to a board which was hinged at the bottom and could be withdrawn when the pendulum swung backward. When this board was pressed forward so that the brass plates were in a position to be touched by the platinum points, it broke the circuit through the magnet just mentioned and released the pendulum.

In order to time the apparatus the time-marker was made to write upon a drum along with a Deprez signal driven by a tuning-fork of 100 vibrations per second. At the first setting up of the apparatus ten clicks were used and occupied in all .11 sec. They were consequently separated from one another by intervals of .011 sec. The apparatus was timed very frequently to ensure constant rate. In the later experiments the pendulum was made to swing through a greater arc. This decreased the interval between the clicks to .0065 sec., and in the last experiments the interval was made .0075 sec. The interval between the two groups of clicks was about .25 sec. This interval varied slightly in different portions of the experiments. The amount of variation in the velocity of the pendulum during the time it was passing the plates could not be detected in the tuning-fork record. In all the experiments the time-marker, besides giving the clicks, inscribed its motions on a smoked drum, by means of which an objective record was kept of what had actually happened, and any failure in the instrument was instantly detected.

In making experiments the operator was seated before the pendulum, managed the switch-board with one hand and brought the brass plates into position with the other, while the subject sat near the time-marker and in such a position as not to see the essential manipulations of the operator. The operator told his subject that there would be a certain number of clicks in the first group, *e. g.*, four, and that in the second group there would be either four or five. The subject was required every time to judge which it was; no answers of "doubtful" were permitted. It was not difficult by means of the switch-board to connect or disconnect a wire while the pendulum passed from the position of contact for one point to that for the other, and any failure to do so was shown by the drum record just mentioned.

Results of the Experiments. The experiments were made upon three subjects, and all numbers from four to ten were used as standards and compared with the numbers greater or less by one. About twenty-four observations were made upon each standard, beginning with four and going up to ten. The order was then reversed, beginning with ten as the standard, and about the same number of observations was made upon all numbers down to four. The following table gives the number of observations and percentages of errors for all the subjects and all the standards.

TABLE I.

Showing number of observations and percentage of errors for all the groups of clicks from three to ten. Interval between the clicks, .011 sec.; between the two groups of clicks, .25 sec. The standard always came first and was compared with either the next higher or the next lower number, but in separate sets of experiments; both higher and lower were not used in the same set.

Groups to be Compared.	H.		S.		B.	
	No. of Observations.	Percentage of Errors.	No. of Observations.	Percentage of Errors.	No. of Observations.	Percentage of Errors.
4—3			48	6.	36	5.
4—5			74	13.	72	12.
5—4	68	10.3	79	24.	48	12.5
5—6	50	26.	58	24.	45	11.
6—5	56	16.	62	16.	46	13.
6—7	54	16.6	53	30.	48	27.
7—6	53	15.1	54	29.	44	18.1
7—8	58	19.	54	28.	48	18.7
8—7	49	6.1	55	13.	48	4.1
8—9	67	20.8	62	33.	48	20.
9—8	52	7.6	46	26.	48	16.
9—10	52	13.4	83	32.	72	18.
10—9	46	19.5	46	33.	54	20.3

From this table it will be seen that on most of the standards, excepting the judgments of S., the percentage of right judgments was greater than 75, the proportion at which knowledge may be assumed to be the basis of the judgment. It is possible then to recognize a difference of one in any number of clicks below ten when the clicks are separated by an interval of .011 sec.

The table also shows that the percentages of errors are greater generally for the greater than for the less number of clicks. This will be more apparent by grouping the percentages on several standards and taking the average of each group.

	H.	S.	B.
First group (standards 4 and 5),	17.2	16.7	13.5
Second group (standards 6, 7 and 8),	13.4	23.2	16.2
Third group (standards 9 and 10)	15.3	31.2	18.5

The strain upon attention was very great, and if any disturbance occurred at the moment the pendulum swung, the judgment was impaired. Very frequently the subject was asked what his opinion of the correctness of his judgments was, or whether any disturbance had distracted his attention. The answers were recorded, and a close correspondence was found to exist between these facts and the accuracy of his judgments. Some observations were taken upon two and three as standards, with an occasional error. With these standards the strain upon the attention was even greater than with larger numbers, and any disturbance was more likely to impair the judgment. In general if judgments could be made immediately they were always more satisfactory; delay was fatal.

It was stated above that the experiments were begun with four as the standard and carried through all the numbers up to ten. The reverse order was then followed to compensate for practice. The results of both are united in the table above. In the second half of the observations the percentages of errors were very much decreased by practice. In the first half H. made 69 errors, S. 113, and B. 61; in the latter half H. made 25 errors, S. 87, and B. 36. On several standards in the latter half, H. and B. made no errors at all. The tendency was to judge more different than alike, though the standard was followed by an equal number, i. e., was repeated, as frequently as by a different number. When the standard was followed by an equal number, H. made 67 errors, S. 96, and B. 63; when the standard was followed by a greater or a less number, H. made 27 errors, S. 87, and B. 39.

In all these experiments the standard had been made to precede the number to be compared. To prevent the possibility of there being a difference in the second group which could not be detected by the record on the drum or the measurements with the tuning-fork, and which served as the basis of judgment, observations were taken in which the number of clicks in the second group remained constant and the number in the

first varied. The standard was eight. The results do not differ from those in the table. S. made 17.5% of errors in 128 judgments, and B. 15.6% in 64 judgments.

Some observations were also taken in which the standard came indiscriminately first or last, with the result that in 64 observations there were 7.8% of errors. The interval between the clicks was .011 sec. The standards were 7 and 8. These experiments are not included in Table I.

All the subjects remarked early in the experiment that when the standard was compared with a less number, they experienced less difficulty in detecting the difference than when the standard was compared with a greater number. The actual numbers of errors from Table I., classified with reference to this point, are found in Table II.

TABLE II.

Giving the number of observations upon the standard and lesser group, and upon the standard and greater group. Conditions as in Table I.

SUBJECT H.

STANDARD AND LESSER GROUP.				STANDARD AND GREATER GROUP.			
Groups of Clicks.	No. of Obser.	Errors on Standard.	Errors on Lesser Group.	Groups of Clicks.	No. of Obser.	Errors on Standard.	Errors on Greater Group.
5—4	68	5	2	5—6	50	8	5
6—5	56	6	3	6—7	54	8	1
7—6	53	5	3	7—8	58	9	2
8—7	49	1	2	8—9	67	11	3
9—8	52	3	1	9—10	52	5	2
10—9	46	6	3				
Totals,	324	26	14		281	41	13
Percent. of Errors,		8%	4.3%			14.5%	4.6%

TABLE II.—*Continued.*

SUBJECT S.

STANDARD AND LESSER GROUP.				STANDARD AND GREATER GROUP.			
Groups of Clicks.	No. of Obser.	Errors on Standard.	Errors on Lesser Group.	Groups of Clicks.	No. of Obser.	Errors on Standard.	Errors on Greater Group.
4—3	48	2	1	4—5	74	6	4
5—4	79	11	6	5—6	58	8	6
6—5	62	5	5	6—7	53	6	10
7—6	54	9	7	7—8	54	8	7
8—7	56	4	3	8—9	62	9	12
9—8	46	7	5	9—10	83	13	14
10—9	46	8	7				
Totals,	391	46	34		384	50	53
Percent. of Errors,		11.5%	8.6%			13%	13.1%

SUBJECT B.

STANDARD AND LESSER GROUP.				STANDARD AND GREATER GROUP.			
Groups of Clicks.	No. of Obser.	Errors on Standard.	Errors on Lesser Group.	Groups of Clicks.	No. of Obser.	Errors on Standard.	Errors on Greater Group.
4—3	36	2	0	4—5	72	3	6
5—4	48	5	1	5—6	45	2	3
6—5	46	4	2	6—7	48	6	7
7—6	44	6	2	7—8	48	4	5
8—7	48	2	0	8—9	48	4	6
9—8	48	8	0	9—10	72	7	6
10—9	54	10	1				
Totals,	324	37	6		333	26	33
Per Cent. of Errors,		11.4%	1.8%			7.8%	9.9%
Grand Totals,		109	54=163			117	99=226

This table means, in the case of H., for example, and the group of clicks marked 5—4, that when he was given by the operator 68 tests, half of which consisted of a group of 5 clicks followed by another group of 5, and half of a group of 5 clicks followed by a group of 4, his description of what had been given him was wrong seven times: five times, when he

was given 5—5, he called it 5—4, and two times, when he was given 5—4, he called 5—5. Similarly with the standard and greater group the first line means that when he was given 50 tests, half being 5 clicks followed by 5 and half 5 followed by 6, he eight times mistook 5—5 for 5—6, and five times mistook 5—6 for 5—5.

The total number of errors upon the standard and lesser group are very much less than upon the standard and greater group (163 to 226), this difference being due almost entirely to the very large number of errors (99) upon the greater group. With two subjects the number of errors upon the greater group is greater than upon the standard, and with all three subjects the number of errors upon the lesser group is decidedly less than upon the standard.

This concentration of the errors was quite unexpected, and seemed so remarkable that the experiment was varied for further investigation of the point.[1] The subject was given a standard followed by the same number, or by a less or greater number, thus making three answers possible. This would make a difference between the greater and lesser groups twice that between either group and the standard. On this account, with standards less than ten, the confusion of the greater with the lesser group, and *vice versa*, was very exceptional.

[1] In the discussion that followed a brief report of these experiments given before the American Psychological Association at its Philadelphia meeting, Prof. Jastrow objected to the description of this result as "unexpected," since Dr. Hall and he had noticed the same in the course of their experiments on rhythm (above referred to). That they did notice this peculiar constant error I can well believe, but no mention of it sufficient to cause anyone to expect it here is to be found in the very condensed account of their experiments. E. C. S.

TABLE III.

Giving the number of observations and the percentages and numbers of errors, when the standard was compared with the same number or with a greater or a less number. The interval between the clicks was .011 sec., and between the standard and comparison groups .25 sec. The standards were 7, 8 and 9.

	Lesser Group.			Standard.			Greater Group.		
Subject.	No of Obser.	No. of Errors.	Per Cent. of Errors.	No. of Obser.	No. of Errors.	Per Cent. of Errors.	No. of Obser.	No. of Errors.	Per Cent. of Errors.
H.	36	3	8.3	36	6	16.6	36	8	22.2
S.	21	3	14.2	21	8	38.	20	8	40.0
B.	24	1	4.1	24	6	25.	24	8	33.3
Total.	81	7	8.6	81	20	24.7	80	24	30.0

Total No. of obser., 242; total of errors, 51; percentage of errors, 21.

TABLE IV.

Conditions as in Table III., except that the interval between the clicks was made .0065 sec.

	Lesser Group.			Standard.			Greater Group.		
Subject.	No. of Obser.	No. of Errors.	Per Cent. of Errors.	No. of Obser.	No. of Errors.	Per Cent. of Errors.	No. of Obser.	No. of Errors.	Per Cent. of Errors.
H.	85	10	11.8	85	26	30.5	85	27	31.8
S.	89	22	24.7	93	36	38.7	89	36	40.4
B.	96	5	5.2	96	31	32.3	96	32	33.3
Total.	270	37	13.7	274	93	33.9	270	95	35.2

Total No. of obser., 814; total of errors, 225; percentage of errors, 27.6.

In both tables the subjects show greater percentages of errors upon the greater group than upon the standard or lesser group, and greater upon the standard than on the lesser

group, thus confirming the results of Table II., and showing that the distribution of the errors does not rest on the particular conditions of the earlier experiments. The percentages of errors for the faster rates are on the whole considerably increased.

An attempt was now made to measure the difference thus discovered by increasing the number of clicks in the greater group. The results appear in Table V.

TABLE V.

Giving the number of observations and percentages of errors, when the greater group was made greater by two clicks than the standard, and by three greater than the lesser group. The interval between the clicks was .0065 sec., and between the two groups .25 sec. The standards used were 6, 7 and 8. With 6 were given 5 and 8; with 7 were given 6 and 9, and with 8 were given 7 and 10 as comparison groups.

	Lesser Group.		Standard.		Greater Group.	
Subject.	No. of Obser.	Per Cent. of Errors.	No. of Obser.	Per Cent. of Errors.	No. of Obser.	Per Cent. of Errors.
H.	42	14.2	42	11.	42	4.9
S.	30	23.3	31	35.6	30	20.
B.	42	7.1	42	19.	42	2.3

The effect of the double increase of the greater group was to reduce the percentages of errors upon it below either those on the standard or on the lesser group. The percentages of errors on the standard have also been reduced, as was to be expected, for increasing the difference between the standard group and the greater comparison group renders the mistaking of the standard for the greater less likely as well as the mistaking of the greater for the standard.

The proportion of errors made on the standard is worth a little further consideration. Table II. shows that the percentages upon the standard were always greater than upon the lesser group, and with one subject greater upon the standard than upon the greater group. What the explanation of this difference is, is not easy to say, for the subject knew in each case that the two groups would be alike as often as they were different. Possibly some qualitative difference, subjective or objective, between the first and second groups, lies at the bottom of it. It was impossible to do away absolutely with

all such differences, and impossible also to say in what the differences consisted. This may have led the subjects to judge the second set to be different from the first more often than they should. But it may also have been wholly subjective. When the subjects were expecting a difference, they found great difficulty in not imagining one, even though there was none.

A more interesting question at present is, however, the greater number of errors upon the greater group as compared with the lesser group as shown in Tables II., III. and IV. and the effect on the distribution of the errors produced by the increased difference between the standard and greater group shown in Table V. In this case the qualitative difference just considered cannot be made the basis of judgment. It seems rather to be a question of the behavior of the memory after-image. There was a kind of subjective feeling of disappointment when a lesser number followed the standard, and of superfluity when a greater number followed. Possibly the explanation should run something like this: The intervals here dealt with are very much shorter than any we meet with in daily experience, and for that reason in attempting to recall such an interval, we may imagine it too large; we think of it as corresponding to other experiences. This enlarged image of the first interval is brought into comparison with the sensation produced by the second and thus the second seems very much shorter than the first. Our memory image of the first actually increases in length during the interval between the first and second sets of clicks. When the lesser group follows the standard, the second seems decidedly less than the first; but when the same or a greater number follows, the difference is not so great and more difficulty in discriminating is experienced. The experiments of Table V. show that the amount of lengthening in the memory after-image was more than compensated by the increase of the difference between the standard and the greater group. The apparent increase in the first group for standards such as were used must, therefore, be in general less than the time of two clicks, that is, .013 sec. It was supposed that this apparent increase might be greater for longer times than the .25 sec. that in these experiments separated the groups, but when the interval between two groups was increased to six seconds, though a slight increase in the percentage of errors took place, their distribution remained practically the same. The question of fatigue may also enter here as a possible explanation. To produce successively and rapidly a sensation of given intensity, the stimulus must be constantly increased. In order, then, that the second set of clicks shall produce a sensation equal to the

first, the second set must be greater than the first. When the second set of clicks is less than the standard, the sensation would fall far short of the first. This would seem to explain the feeling of relief which followed so perceptibly on the lesser comparison, but it involves the supposition that the number of clicks or the time they occupy is inferred from the intensity of the general effect that is produced.

Tables III. and IV. have been considered so far in relation to the distribution of the errors only. They bear, however, upon the general question of the investigation. Table III. reinforces Table I. in showing that, for two observers at least, a difference of one in excess or defect can be recognized with a standard group of 8 clicks separated by intervals of .011 sec. Table IV. shows that the same is true when the intervals are reduced nearly one-half, namely, to .0065 sec., though the percentage of errors is somewhat greater. Results obtained from experiments where the subject is given three possibilities of answer are not strictly comparable with those in which only two possibilities are offered, but so long as there is no tendency to confuse the greatest and the smallest of the three stimuli (for example, in the experiments giving these tables, to call a 7-click group a 9-click group, or *vice versa*), the case is not very different from that of the two-possibility experiments. In the experiments giving Tables III. and IV. there were very few answers of this doubly wrong kind, and 75% of right answers may be assumed as the measure of discrimination, as in the experiments giving Table I.

With the apparatus used it was impracticable to attempt a further shortening of the intervals beyond .0065 sec.; accordingly attention was turned to the effect of increasing the number of clicks in the groups, with a view to discovering if possible the limit in number for an interval that was easily at command; in this case .0075 sec. $= 133+$ clicks per sec. Tests were made with groups of 13, 16 and 23 clicks as standards. The results reached are grouped in the following table :

TABLE VI.

Giving the number of observations, the number of errors, and the percentage of errors, when the standard was compared with the same number or with a greater or a less number. The interval between the clicks was .0075, that between the groups .25 sec.

STANDARD 13.

Subject.	LESSER GROUP.			STANDARD GROUP.			GREATER GROUP.		
	No. of Obser.	No. of Errors.	Per cent. of Errors.	No. of Obser.	No. of Errors.	Per cent. of Errors.	No. of Obser.	No. of Errors.	Per cent. of Errors.
H.	17	0	0	24	15	62.5	22	11	50
S.	25	11	44	25	13	52	25	11	44
B.	22	3	13.6	21	10	45.7	21	9	23.3

Total number of observations, 202; total of errors, 83; percentage of errors, 41.9.

STANDARD 16.

Subject.	LESSER GROUP.			STANDARD GROUP.			GREATER GROUP.		
	No. of Obser.	No. of Errors.	Per cent. of Errors.	No. of Obser.	No. of Errors.	Per cent. of Errors.	No. of Obser.	No. of Errors.	Per cent. of Errors.
H.	32	13	40.6	26	13	50	33	15	45.4
S.	35	9	25.7	39	22	56.4	32	12	37.5
B.	29	10	34.8	28	11	39.2	29	12	41.4

Total number of observations, 283; total of errors, 117; percentage of errors, 41.3.

TABLE VI.—*Continued.*

STANDARD 23.

Subject.	LESSER GROUP.			STANDARD GROUP.			GREATER GROUP.		
	No. of Obser.	No. of Errors.	Per cent. of Errors.	No. of Obser.	No. of Errors.	Per cent. of Errors.	No. of Obser.	No. of Errors.	Per cent. of Errors.
H.	18	11	61.1	21	12	57.1	22	10	45.4
S.	26	15	57.7	28	17	60.6	26	13	50
B.	17	7	41.1	27	18	66.6	21	8	38

Total number of observations, 206; total of errors, 111; percentage of errors, 53.8.

The percentages that the total number of errors are of the whole number of observations on any standard have increased with the increase of the standard. Errors resulting from a confusion of the lesser group with the greater are much more frequent upon 23 as the standard than upon 13 or 16. The percentages of such errors of the whole number of observations are, on 13, 5.4%; on 16, 5.3%; and on 23, 17.4%. The impossibility of judging the difference of one click with a group of 23 when they are separated by .0075 sec., is not to be doubted; only 66.6% of errors would be expected if the answers were dictated wholly by chance. For 13 and 16 the number of right answers is considerably more than could be expected from chance, but considerably less than the required 75%, if we apply the criterion of the two possibility experiments. It would seem then that the ability to recognize a difference of one click under the conditions of these experiments does not extend far beyond groups of 8 or 10 clicks and fails completely at something over 23.

It remains to speak of whether these are time or number judgments. The separate clicks could be apprehended, but counting was out of the question, and it was impossible by any voluntary muscular adjustment to name or record the number. The number of clicks in the group seemed often, if not always, less than the number actually known to be present. The only attempt on my part towards a muscular adjustment was to contract the muscles of the tongue and

larynx twice in rapid succession in such a way as to produce a grating sound when the vocal cords were made to vibrate, thus imitating the groups of clicks to be compared. This took place when I was in doubt. The decision was based upon what seemed to be an equal or an unequal amount of stimulus. An introspective account of how the groups were compared is difficult, because of the extreme concentration of attention required. If the judgment is a number judgment at all, it is something quite different from the number judgments of daily life, possibly akin to the quantitative estimates of groups of objects made by animals and by children before they have learned to count, and, indeed, by adults when for any reason counting is not easy. That time judgments also played a part seems very probable; and the fairest description of the experiments undoubtedly is to say that they are judgments of filled time.

Summary. The experiments that have been described make the following answers to the questions at the beginning of the paper: To question 3 the answer is that the presence of one more or one less click in successive groups can be recognized (probably by the greater length of time required for the larger group) when the number of clicks is not too large and their rate not too rapid. When the rate is 133 per sec., the number cannot very much exceed 10, though with groups of 13 and 16 a difference of one can sometimes be recognized. When the number of clicks is 9 or less the rate may rise at least to 153 per sec., and perhaps higher.

To question 2 the answer is that it is extremely improbable that any clicks are lost in the perception of a rapid group at least up to 153 per sec.; for groups of 8 and 9 can be distinguished at that rate. If the experiments involve a time judgment, it is clear that one one-hundred-and-fifty-third of a second can be recognized, and if so, there would be no need that the images of clicks at that rate should over-lap in consciousness—over-lapping was the cause of loss in Hall and Jastrow's counting experiments. If the judgment was a number judgment, the loss would also seem to be excluded. In some cases where a temporary defect in the instrument caused the actual dropping of a click from the middle of a group, this fact was very easily recognized, though this of course is quite a different thing from the unconscious subjective dropping implied in the question. Particulars as to rates at which this dropping occurred have unfortunately not been preserved, but the statement is believed to be true for all rates.

To question 1 the answer is that for the mere perception of discreteness, number is probably without influence. The fact

that it is less easy to tell 10 clicks from 9 than 5 from 4 shows only that a difference of 1 in 10 is less easy to recognize than a difference of 1 in 5, a result that accords with the psycho-physic law. With reference to the tendency to blend, such a result shows nothing. No greater tendency to blend in the case of the larger numbers was noticed by the subjects. When the question is one of estimating the number of clicks, a slower rate for larger numbers may very well be required.

A few words upon the work of others on related topics will serve to put the results of this study in their proper perspective. Exner found in his studies of reaction-times[1] that his subjects could tell "good" (i. e., quick) reaction-times from slow ones when the difference amounted to about .01 sec., thus seeming to show an ability to perceive a time as small as that amount.

The general form of these experiments is not so very different from those of Dietze's work on the *Umfang* or extent of consciousness,[2] but the intervals used were very much smaller than his, his shortest being .11 sec., or exactly ten times the largest in these experiments. He also found a decided falling off in ability to judge correctly when intervals less than .24 sec. were used, a result different from Mr. Bolton's, but one that may depend either on a difference in experimental conditions, or on a difference in the manner in which groups of clicks of such different rates are judged. Mr. Bolton's subjects found no tendency to such rhythmical sub-grouping of the clicks as Dietze found.

The work of Hall and Jastrow, already mentioned, is somewhat analogous, but different both in the size of the intervals (theirs being .0895 and .0523) and the mental process involved, the effort in their case being generally to count the clicks, or at least to estimate them in numbers. In Mr. Bolton's experiments counting was out of the question. Their observation that filled time seems longer than vacant time could be frequently repeated in these experiments. When, as was natural, attention was concentrated upon the groups of clicks, each group seemed clearly longer than the empty time between them, though with even the most numerous groups the latter was a full third longer. The function of attention in this illusion is certainly a very important one.

Dr. F. Schumann has published two papers on the comparison of small intervals of time; the first in the *Nachr. v. d. Ges. d. Wiss. zu Göttingen*, 1889, No. 20, and the second (a preliminary communication) in the *Zeitsch. für Psychol.* II. 1891, 294–296. Schumann's experiments, however, were made upon empty intervals of time, and though short, did not approach in brevity those of Mr. Bolton, his shortest reported being .15 sec. The same experimenter has repeated in part the work of Dietze with practically the same numerical results, but with a totally different conclusion as to their meaning.[3] Schumann believes that when two such groups are compared the process is somewhat as follows: Each member of the first group as it arrives is registered in memory (in some cases this is clearly done by an accompanying muscular contraction). When the second group is received there is a tendency for the first to be

[1] Pflüger's Archiv, VI. 1873, p. 613—. But see also an explanation of Wundt's (Physiol. Psychol. 3rd Ed. II. 288), which rests upon other than a time discrimination.
[2] Wundt: Physiol. Psychol. 3rd Ed. II 248–252. Dietze, Philos. Studien II.
[3] Zeitschrift für Psychologie, I. 1890, 75–80.

reproduced in its original number. If the second group contains more clicks than the first, the tendency to reproduction ceases before the cessation of the actual clicks of the second group; if the second contains a less number, the tendency over-runs; if the same number, both tendency and clicks cease together. On these inner experiences the judgment of the subject rests. The "feeling of too much or too little" that Mr. Bolton's subjects speak of, might well point to something of this kind. Its origin, however, could hardly in this case be a muscular response to each click, unless, perhaps, the tympanic muscles respond reflexly, for the most rapid voluntary movements are very much slower than the slowest clicks used in his experiments. If the tendency to reproduce a group of clicks in its exact number is a function of the sensory parts of the cerebrum, there would seem to be no difficulty in explaining the judgment of even these very rapid groups on Schumann's hypothesis.

E. C. S.